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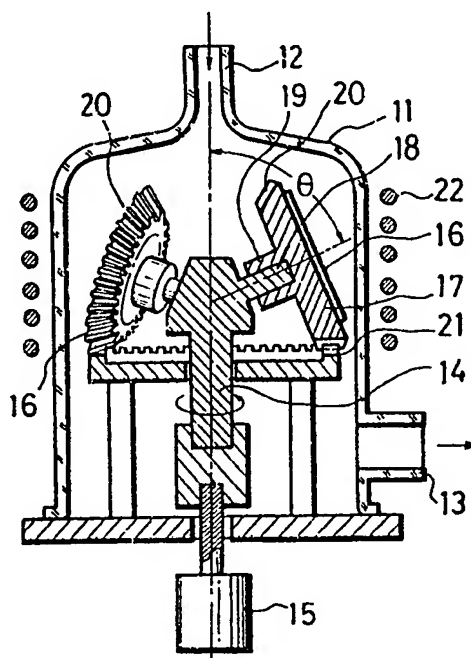
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US 3598083

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C7F  
Selected US specifications from IPC sub-class C23C

(54) Vapour deposition apparatus  
and epitaxial layer growth methods

(57) An apparatus for vapour deposition of semiconductor materials on a semiconductor wafer includes a reaction chamber (11), an inlet (12) for introducing a reaction gas into the reaction chamber, and an outlet (13) for discharging spent reaction gases from the chamber. A support means (14) is provided within the chamber (11), and means (15) is provided for rotating the support means about an axis thereof. A susceptor (17) is mounted on the support means (14) at an angle which is an acute angle to the axis of the support means, being neither horizontal nor vertical, and supports a semiconductor wafer (16) positioned against it. During a chemical reaction which deposits a semiconductor material on the wafer (16), the wafer is rotated about an axis of the susceptor (17) on which it is supported and also is rotated about a central axis of the reaction chamber (11) in a direction normal to a direction in which the reaction gas enters the chamber.

FIG. 3



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FIG. 1

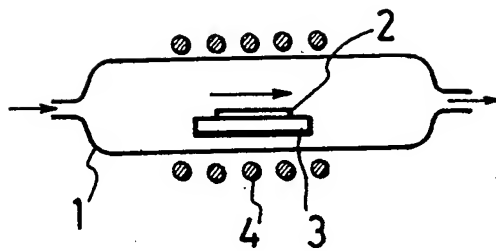


FIG. 2

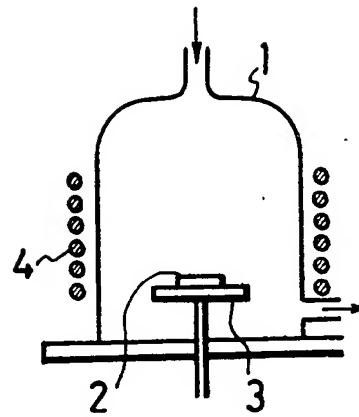
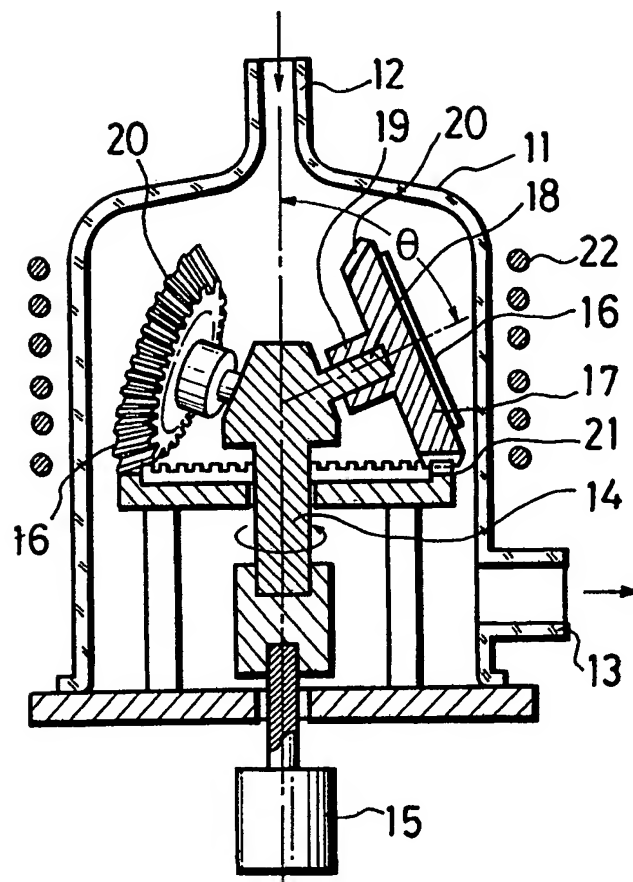


FIG. 3



## SPECIFICATION

**Vapour deposition apparatus and epitaxial layer growth methods**

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This invention relates to vapour deposition apparatus for growing a layer (for instance a layer of a semiconductor material) on a semiconductor wafer by vapour deposition, for example chemical vapour deposition (VCD) or metal-organic chemical vapour deposition (MOCVD), and to methods of growing an epitaxial layer on a semiconductor layer.

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Previously proposed apparatus for vapour deposition can be divided into apparatus of two distinct types. One type comprises a reaction tube, generally made of quartz and disposed horizontally, through which a reaction gas is passed from one end to the other. A support plate or susceptor is disposed within the reaction tube for supporting a semiconductor wafer or the like on which reaction products are grown epitaxially. The susceptor is heated by a high frequency coil so that the wafer or wafer substrate reaches a temperature suitable for deposition of a semiconductor layer compound as an epitaxial layer on the wafer. The second type of vapour deposition apparatus employs a reaction tube or chamber comprising, for example, a bell jar having a longitudinal axis, the reaction gas being caused to travel from an upper portion of the jar to a lower portion thereof. A support plate comprising a susceptor which supports a semiconductor wafer is located substantially perpendicularly to the direction in which the reaction gas is introduced. In this type of apparatus, the susceptor is rotated within a horizontal plane while being heated and while the reaction gas impinges vertically on the wafer.

Whether the previously proposed deposition apparatus employs a reaction tube of the horizontal type of the longitudinal type, it is frequently difficult to carry out a uniform epitaxial growth on the semiconductor wafer. In the horizontal type apparatus, since the semiconductor wafer is disposed substantially along the lines of flow of the reaction gas there tends to be a difference in the growth velocity between portions which are upstream and downstream of this inlet. Such a difference in growth speed becomes quite substantial when the number of semiconductor wafers is increased. In the longitudinal type apparatus, the vapour growth speed is different relative to the radial direction of the susceptor and, therefore, the composition of the epitaxially grown layer is not uniform.

According to one aspect of the invention there is provided a vapour deposition apparatus for growing a layer on a semiconductor wafer by vapour deposition, the apparatus comprising:

- a reaction chamber,
- inlet means for introducing a reaction gas into the reaction chamber,
- a support means in the reaction chamber,
- means for rotating the support means about an axis thereof,

and having an axis thereof disposed at an acute angle to the axis of the support means, the susceptor means being arranged so that a semiconductor wafer can be positioned against it, and

means for rotating the susceptor means about its axis.

According to another aspect of the invention there is provided a method of growing an epitaxial layer on a semiconductor wafer, the method comprising:

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positioning the wafer on a susceptor capable of being inductively heated by high frequency electromagnetic radiation in the reaction zone,

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directing substantially downwardly through the reaction zone a reaction gas which reacts under the temperature conditions in the reaction zone to form a layer on the wafer,

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rotating the susceptor and the wafer during such reaction about an axis of the susceptor which is inclined from both horizontal and vertical planes of the reaction zone, and

rotating the susceptor and the wafer during such reaction about a substantially vertical rotational axis.

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A preferred embodiment of the present invention described hereinbelow provides a method and apparatus for vapour deposition suitable for use in conjunction with metal-organic chemical vapour deposition (MOCVD) and other chemical vapour deposition (CVD) processes. It provides an apparatus which is capable of depositing on a wafer a vapour deposition layer which is uniform in thickness and composition. Through the use of the apparatus, the vapour growth speed and composition of a layer grown on a semiconductor wafer can be made uniform. The preferred apparatus and method also avoid disadvantages such as the occurrence of polycrystalline growth and the like in the process of epitaxial growth.

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In the preferred embodiment, a reaction gas containing compounds which decompose under the reaction conditions to form a desired semiconductor layer is passed into a reaction tube, such as a bell jar, of the longitudinal type in a vertical direction from an upper portion to a lower portion so that the reaction gas flows mainly in the vertical direction. A plurality of support tables or susceptors for supporting wafer substrates or wafers on which vapour deposition growth is to be carried out are disposed concentrically about the central axis of the reaction tube in which the reaction gas is travelling at an angle which is neither perpendicular to the main direction of flow of the reaction gas nor parallel thereto but has a predetermined inclination to both directions. Means is provided in association with the susceptors for rotating the respective susceptors on their own axes while supporting planes thereof are at the above-mentioned inclination. While the susceptors are rotated about the angularly disposed axes, they are also rotated within the reaction tube along a substantially horizontal plane, that is a plane substantially normal to the flow of the reaction gases within the tube. Since the susceptors for supporting the semicon-

also revolve with a predetermined inclination relative to the flow of the reaction gas, the semiconductor wafer on each of the susceptors contacts the flow of the reaction gas under substantially uniform conditions. Therefore, the growth speed and the composition can be made uniform with respect to all the semiconductor wafers and to portions within each semiconductor wafer.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawing, in which:

Figure 1 is a somewhat schematic view of a previously proposed apparatus of the horizontal type used for chemical vapour deposition;

Figure 2 is a somewhat schematic view of a previously proposed apparatus of the vertical type used for vapour deposition processes; and

Figure 3 is a longitudinal cross-sectional view of a vapour deposition apparatus embodying the present invention.

A previously proposed form of vapour deposition apparatus used for chemical vapour deposition processes such as MOCVD is shown in Figure 1. The apparatus comprises a reaction tube 1 of the horizontal type, composed of quartz, through which a reaction gas is passed from one end to the other as shown by arrows. Inside the reaction tube there is disposed a support plate or susceptor 3 made of graphite or the like for supporting a substrate or semiconductor wafer 2 on which vapour deposited epitaxial growth is to occur. The reaction gas flows across a face of the semiconductor wafer 2 as shown. The susceptor 3 is heated by a high frequency coil 4. The semiconductor wafer 2 supported on the susceptor 3 is thus heated to a predetermined substrate temperature, and a desired CVD layer such as a compound semiconductor layer is grown epitaxially on the semiconductor wafer 2 by thermal decomposition of the reaction gas which passes over the semiconductor wafer 2 while in contact therewith.

A second previously proposed form of vapour deposition apparatus is illustrated in Figure 2. This comprises a reaction chamber located in a bell jar 1 made of quartz or the like. A reaction gas is sent from an upper portion to a lower portion of the bell jar 1 as illustrated by arrows. A support plate such as a susceptor 3 supports a semiconductor wafer 2 in substantially normal relationship to the flow of the reaction gas, namely in a horizontal plane, and the susceptor 3 is rotated within the horizontal plane.

Both of the illustrated previously proposed forms of apparatus are subject to the disadvantage that the speed of deposition and growth varies and the composition of the deposited material is likely to be non-uniform.

Figure 3 shows a vapour deposition apparatus embodying the present invention, which includes a reaction tube 11 of the longitudinal type which comprises, for example, a quartz bell jar. A supply inlet 12 for a reaction gas is formed at the upper end of the reaction tube 11 substantially on its axis, and an exhaust outlet 13 for discharging

of the reaction tube 11, for example, as shown, on one side. In this way, the main flow of the reaction gas is substantially along the axis of the reaction tube 11, which is indicated by a chain-dotted line.

Along this axis there is supported a support means of a drive motor 15.

At least one disc-shaped support table 17, constituting a susceptor for supporting a semiconductor wafer 16, is pivotally mounted at the upper end of the rotary shaft 14. Preferably, as shown, a plurality of such susceptors 17 for supporting respective wafers 16 are so mounted. The susceptors 17 are disposed at an equal angular spacing around the shaft 14. For example, if three susceptors 17 are provided, the susceptors are disposed with an equal angular spacing of  $120^\circ$  between them about the shaft 14. Each susceptor 17 is disposed such that a planar surface thereof on which the semiconductor wafer 16 is placed faces the inner wall or surface of the reaction tube 11 with an inclination which is between the horizontal and the vertical. Each susceptor 17 is positioned such that an axis thereof which is perpendicular to the planar surface thereof, that is, the direction of the plane on which the semiconductor wafer 16 rests, intersects the main flow direction of the reactive gas or the vertical direction at a predetermined angle  $\theta$ , which lies, for example, in the range of  $80^\circ$  to  $10^\circ$ . Each susceptor 17 is pivoted to the shaft 14 so as to be freely rotatable by virtue of a boss 19, having a cylindrical recess, which is formed at the back of the susceptor 17. A cylindrical shaft 18 extending from the shaft 14 extends into the boss 19. Rotation means is provided to rotate each of the susceptors 17 about its own axis. The rotation means may, for example, comprise a bevel gear 20 on the outer peripheral surface of each disc-shaped susceptor 17 which meshes with a crown gear 21 located about the rotation shaft 14 and concentric therewith. The crown gear 21 is located within a horizontal plane perpendicular to the shaft 14.

When a high frequency coil 22 is supplied with high frequency energy, it heats the or each susceptor 17 by induction so as to heat the semiconductor wafer to a predetermined temperature.

The or each susceptor 17 located within the reactor tube 11 is made of graphite or silicon carbide (SiC) and the shaft 14, the crown gear 21 and the bevel gear 20 are each made of quartz, graphite, a refractory ceramic or SiC, which are inert materials and do not produce impurity gases, and which also have good heat-resistant properties. The or each susceptor 17 can be moulded integrally with the bevel gear 20 that is provided on the outer periphery of the susceptor 17 or the support plane for supporting the semiconductor wafer 16 and the bevel gear 20 provided on the outer periphery can be made independently of different materials. Consequently, they can be integrated together. Various methods of construction can be employed. When the or each susceptor 17, particularly the boss 19 thereof, and the shaft 14, particularly the cylindrical shaft 18 projecting therefrom, are made of graphite, the boss 19 and the shaft 18 can slide smoothly with respect to each other and the reactor 17 can

be rotated smoothly.

In the above-described vapour deposition apparatus embodying the invention, when the vapour reaction medium includes components for making the compound semiconductor AlGaAs, together with a carrier gas, such as hydrogen gas, the reaction gas may comprise trimethyl aluminium, trimethyl gallium, and arsine. The reaction gas mixture is supplied to the reaction tube 11 through the supply inlet 12 with a predetermined molecular ratio. In this way, the gases are allowed to contact the semiconductor wafer 16 placed on the susceptor or supporting tables 17. The shaft 14 is then rotated by the drive motor 15. All of the susceptor 17 supported by the shaft 14 are rotated or revolved around the shaft 14 with a predetermined positional relationship being maintained throughout the rotation of the shaft 14. At the same time, each of the susceptor 17 is rotated on its own axis by the engagement of the crown gear 21 with the bevel gear 20 provided with the periphery of the susceptor. Consequently, while each of the semiconductor wafers 16 supported on the susceptor 17 is being rotated on its axis, it is also being revolved about the axis of the reaction tube 11. Thus, the respective portions of each of the semiconductor wafers 16 supported on the susceptor 17 are impinged upon the flow of reaction gas under substantially the same conditions.

The or each susceptor 17 is shown as supporting a single semiconductor wafer 16. However, it is also possible for a plurality of semiconductor wafers 16 to be supported on the or each susceptor 17.

As described above, since the semiconductor wafer 16 is rotated on its own axis and also revolved within the reaction tube 11, all of the semiconductor wafers 16 can be contacted uniformly with the reaction gas over their entire areas. Therefore, it is possible to avoid or at least reduce non-uniformities in the reaction speed and the composition being deposited.

Furthermore, since the or each susceptor 17 is positioned so that the surface of the semiconductor wafer 16 does not face the flow of the reaction gas, the reaction gas can be prevented from staying in the region of the surface of the semiconductor wafer 16 whereby the semiconductor wafer 16 always is in contact with a new increment of the reaction gas so that the vapour growth can be carried out positively. Consequently, it is possible to avoid difficulties such as the occurrence of polycrystalline substances in the process of epitaxial growth.

Although the or each susceptor 17 generally tends to have a high heating temperature at its outer peripheral portion located near the heating coil 22, the bevel gear 20 on the outer periphery of the susceptor 17 engages with the crown gear 21 so as thereby to radiate the heat away. Accordingly, the present vapour deposition apparatus has the advantage that the temperature difference between the central portion and the outer peripheral portion of the susceptor 17 can be made relatively

vapour reaction or the vapour epitaxial growth can be carried out uniformly.

## CLAIMS

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1. A vapour deposition apparatus for growing a layer on a semiconductor wafer by vapour deposition, the apparatus comprising:

a reaction chamber,

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inlet means for introducing a reaction gas into the reaction chamber,

outlet means for discharging spent reaction gas from the reaction chamber,

a support means in the reaction chamber,

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means for rotating the support means about an axis thereof, susceptor means provided on the support means and having an axis thereof disposed at an acute angle to the axis of the support means, the susceptor means being arranged so that a semiconductor wafer can be positioned against it, and

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means for rotating the susceptor means about its axis.

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2. Apparatus according to claim 1, wherein a plurality of susceptor are arranged concentrically about the support means and the inlet means is arranged to direct reaction gas substantially downwardly at the angularly disposed plurality of susceptor.

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3. Apparatus according to claim 2, wherein the plurality of susceptor are disposed with their axes at inclinations of from 10° to 80° with respect to the rotational axis of the support means.

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4. Apparatus according to claim 1, claim 2 or claim 3, including means for supplying the inlet means with a reaction gas containing compounds which will decompose to cause the layer grown by the vapour deposition to be of AlGaAs.

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5. Apparatus according to any one of the preceding claims, wherein the susceptor is a disc-shaped susceptor including a boss on a back surface thereof, a cylindrical shaft projects from the support means and is received in the boss, a bevel gear is formed on the outer peripheral surface of the disc-shaped susceptor, and a crown gear concentric with the rotational axis of the support means meshes with the bevel gear.

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6. Apparatus according to claim 5, wherein the disc-shaped susceptor is composed of graphite.

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7. Apparatus according to claim 5, wherein the disc-shaped susceptor is composed of SiC.

8. Apparatus according to claim 5, wherein the crown gear and the bevel gear are made of quartz, graphite, a refractory ceramic, or SiC.

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9. A method of growing an epitaxial layer on a semiconductor wafer, the method comprising: positioning the wafer on a susceptor capable of being inductively heated by high frequency electromagnetic radiation in a reaction zone, directing substantially downwardly through the reaction zone a reaction gas which reacts under the temperature conditions in the reaction zone to form a layer on the wafer, rotating the susceptor and the wafer during such

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clined from both horizontal and vertical planes of the reaction zone, and rotating the susceptor and the wafer during such reaction about a substantially vertical rotational

5 axis.

10. A method according to claim 9, wherein the susceptor is composed of graphite or SiC.

11. A method according to claim 9 or claim 10, wherein the reaction gas contains compounds  
10 which decompose to form a layer of AlGaAs on a surface of the wafer.

12. A method according to claim 9, claim 10 or claim 11, which includes inductively heating the susceptor from outside of a reaction chamber con-  
15 taining the wafer and susceptor.

13. A vapour deposition apparatus substantially as herein described with reference to Figure 3 of the accompanying drawing.

14. A method of growing an epitaxial layer on a  
20 semiconductor layer, the method being substantially as herein described with reference to Figure 3 of the accompanying drawing.